EVALUATION THE SOCIAL ACCEPTANCE OF WASTE TREATMENT TECHNIQUE USING FUZZY SET THEORY

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Abstract: In making the decision on application and planning of waste treatment technique, as well as assessing their sustainability, the social aspect must be taken into account. In recent years, it is becoming evident that a waste treatment technique, which ignores social aspects, is doomed to failure. The social non-acceptance has often been an obstacle to the development and execution of waste treatment technique. Social indicators commonly used are: number of jobs created, social acceptance, public knowledge, public health etc. The most of social indicators are qualitative, and measuring sustainability and quantifying the social dimension of sustainability are difficult tasks. In this paper, an analysis in order to evaluate two social indicators: social acceptance i public knowledge, was done. A set of questionnaire comprising 13 questions with pre-selected answers was applied as instrument for data collection. The analysis was also conducted in order to establish the connection between social acceptance and public knowledge. Due to the lack of data, and qualitative character of indicators, and also to include knowledge and gained experience on the process, fuzzy set theory and fuzzy logic was used to develop fuzzy model for the evaluation of level of social acceptance. The research was performed by using the City of Niš as a case study. The results obtained can be used for ranking of waste management scenarios in the sustainability assessment.

Keywords: Social indicators, waste management, social acceptance, public knowledge, fuzzy set theory, fuzzy model.

INTRODUCTION

Quantifying the social dimension of sustainability is difficult task. The difficulty arises from the need to identify an objective definition of social sustainability, as it is impossible to reach consensus on all the specific ingredients in social sustainability. For a waste treatment technique to be deemed socially sustainable, it should at minimum enjoy wider social acceptance. Therefore, the social sustainability dimension is approached from an angle of social acceptance (Assefa & Frostell 2007). In order to develop the set of social indicators for the assessment of societal effects of energy systems, Carrera & Mack (2010) interviewed scientific experts from four sample countries France, Germany, Italy and Switzerland. The indicator set covers the four main criteria: security and reliability of energy provision; political stability and legitimacy; social and individual risks and quality of life.

However, decision-makers need to consider not only what experts know but also what the public thinks and feels. Depending on the circumstances, there might be an association between what the public thinks and feels, and its knowledge. Different levels of perceptions, to the extent of expressed fear at the public level, can result in a lag between the time when decision-makers express their interest in going forward with a proposed initiative, and the time the proposal wins acceptance by a majority of the public (Assefa & Frostell 2007). This type of delay can manifest itself anywhere in the decision-making process. For example, it took Swedish society more than 20 years to feel a lower level of fear associated with nuclear power, even though the technology has not changed during that time. Implementation of long-lasting, new technical systems, require acceptance by the public. The social acceptance shortens the time between the first discussions of new technical systems and their implementation and makes the system sustainable. Social acceptance is not simply a set of static attitudes of individuals; instead it refers more broadly to social relationships and organizations, and it is dynamic as it is shaped in learning processes (Wolsink 2010). The acceptance among various parts of society has to be studied. Wilson et.al (2001) conducted the study which centered around nine European waste management programs that were seen as advanced programs in their countries concludes that successful waste management programs have one major factor in common: all programs considered the issues of social acceptance and communication to be very important. Scientists agree that social acceptance is considered most critical for the effectiveness of any integrated municipal solid waste management system. Especially for alternatives widely debated, such as waste-to-energy in areas without any prior experience, the widely discussed “Not In My Back Yard” (NIMBY) syndrome needs to be considered when planning the development of the required infrastructure (Achillasa et al. 2011). Despite the fact that “it is becoming increasingly evident that a waste management program and especially a waste treatment technique, which ignores the social aspects is doomed to failure” (Joos et al. 1999), it is only in very recent years that waste management programs and policies are taking the social aspects into account and indicators for sustainable waste management are being developed. These social aspects include the problems of communication, social acceptance, (NIMBY/social compatibility), public participation in planning and implementation, consumer behavior, intergenerational factors and changing value systems.

Social acceptance of waste management models has been a key part of many researches. A comparative study on three environmental policy domains in the Netherlands was done by Wolsink (2010), all deal with legitimizing building and locating infrastructure facilities: renewable energy, water, and waste facilities. Social acceptance of a permanent nuclear waste disposal facility in New Mexico (Jenkins-Smith et al. 2011) and a waste-to-energy plant in an urban area in Greece (Achillasa et al. 2011) was investigated. Zhang et al. (2012) used direct face-to-face interviews and a structured questionnaire survey in four different Shanghai community types, in order to do an econometric analysis of the social factors that influence the willingness to pay for municipal solid waste separation. De Fao and De Gisi (2010) conducted the survey to analyze the people's environmental knowledge in order to select the areas and age groups with a low level of knowledge of municipal solid waste and separate collection programs in a Italian municipality. The other study conducted by De Fao et al. (2013) verified the effects of the closure of solid waste treatment and disposal facilities (two landfills and one RDF production plant) on public perception of odor and environmental pollution. De Fao, (2014), also investigated behaviors, opinions and knowledge of citizens on municipal solid waste and separate collection.

This paper presents a developed fuzzy model for evaluation of level of social acceptance of certian waste treatment, based on fuzzy set theory and fuzzy logic. The research was conducted within the framework of sustainability research different waste management scenarios in Niš, because there is no adopted model of waste management in addition to waste disposal to landfill. The survey was carried out of the sample of 571 respondents in the adult population. A set of questionnaire which comprised of 13 questions was applied as an instrument for data collection, which was used to accumulate knowledge and experience to be included in fuzzy model.

FUZZY SET THEORY AND FUZZY LOGIC

In recent years, fuzzy logic has been successfully applied in a variety of disciplines including environment and waste management, because they provide an approach to deal with uncertainty. Social indicators (social acceptability, job creation, social benefits, social equity, etc.) are mostly qualitative character and determination of social indicators involves a great deal of uncertainty. Those are the main reasons for using fuzzy set theory and fuzzy logic in order to evaluate the social acceptance of waste treatment technique.

Bonvicini et al. (1998) applied fuzzy logic to the risk assessment of the transport of hazardous materials by road and pipeline in order to evaluate the uncertainties affecting both individual and societal risk estimates. To solve the problem of sitting a new landfill, Al-Jarrah and Abu-Qdais (2006) used an intelligent system based on fuzzy inference. Fuzzy logic was also used by Gupta et.al. (2003) to select an appropriate landfill site with minimal environmental damage, and for a rapid and effective assessment of pollution hazard connected with the presence of uncontrolled landfills by Caniani (2011). Sadiqa and Husain (2005) conducted the study to develop and evaluate a hierarchical model of aggregative environmental risk for assessing various drilling waste discharge scenarios for disposal into the marine environment on the basis of fuzzy set theory. The research done by Boclin and De Mello (2006), presented a decision support method for environmental impact assessment, using a fuzzy logic computational approach. It aims at offering stakeholders a way to operate fuzzy and crisp variables and make inferences from resultant values of the systemic indicator as well as environmental, cultural, social and economic thematic indicators. A decision analysis based model has been developed by Mohamed and Cote (1999) to evaluate risks that polluted sites might pose to human health. Concepts of fuzzy set theory have been adopted to account for uncertainty in the input parameters which are represented by fuzzy numbers.

Fuzzy sets are sets with imprecise boundaries. A fuzzy set provides a mechanism to express the degree of membership rather than accepting or denying the membership. It assigns each element in the universe of discourse a value representing its grade of membership in the fuzzy set (Al-Jarrah & Abu-Qdais, 2006). This number represents the certainty or belief this individual is compatible with the concept represented by the fuzzy set. The wide use and popularity of fuzzy set is related to its ability to tolerate imprecise and linguistic data.

Fuzzy logic is basically a multi valued logic that allows intermediate values to be defined between conventional evaluations, such as yes/no, true/false, black/white, and so on; it provides a remarkably simple way to draw definite conclusions from vague, ambiguous, or imprecise information (Klir & Foger, 1988). In a sense, fuzzy logic resembles human decision making in its ability to work from approximate data and find precise solutions. This type of logic is different from the traditional logic due to the possibility to assign a given statement an intermediate level of truth between „false“ and “true”, thus allowing the management of partially true assertions, and putting itself, by this, in a better analogy with the human way of thinking (Caniani et al., 2011). The main phases of the fuzzy approach are the following: the definition of the membership functions, fuzzification, inference and fuzzy output.

A membership function (MF) is a curve that maps each element in the input space into a membership value called the degree of membership. The only restriction on the MF is that it must vary between 0 and 1. The function itself may take any shape that is defined and specified by the designer to suit the nature of the problem from the point of view of simplicity, convenience, speed and efficiency (trapezoidal, triangular, Gaussian, etc.).

The following phase, fuzzification, consists of attributing to a given input parameter its level of membership to the different fuzzy sets in which the dominion of existence of the parameter is subdivided. Using this operation, we normalize all the data within the interval [0,1] so that it is also possible to make comparisons between quantities different from each other and measured in different scales. Fuzzy sets representation conforms to the objectives appearing in our daily linguistic usage such as “small”, “medium” or “large”. These expressions are called linguistic values and the universe of discourse on which these values are defined on is called a linguistic variable.

Inference is the phase when we apply the rules of combination between the fuzzy sets, and from which it is possible to deduce a result. The rules are linguistic expressions which are turned into a mathematical formalism by using the expression “if...then” of the logic itself. Fuzzy reasoning, known also as approximate reasoning, is the process of deriving conclusions from a set of IF–THEN fuzzy rules using an inference procedure. By fuzzy reasoning, the truth of the consequent is inferred from the degree of truth of the antecedent.

Defuzzification consists in drawing the output deterministic value from the fuzzy model. A careful analysis of the problem is at the basis of a correct defuzzification: it can be linguistic, when the output is a predicate to which a level of membership is associated, or numerical, of “crisp” type (non-fuzzy).

EXPERIMENTAL RESEARCH

Study area

City of Niš is situated in south east of Republic of Serbia, in the Nišava valley. It is located at the 43°19' latitude north and 21°54' longitude east. The central city area is at 194 m altitude above sea level. The city area covers 596.71 km^2 of five municipalities: Medijana, Palilula, Pantelej, Crveni Krst i Niška Banja (City of Nis, 2015). In the City of Niš, according to the census of 2011, lived 260,237 inhabitants, while 215,381 are adults (Statistical Office of the Republic of Serbia, 2012), so according to the population, Niš is the third largest city in Serbia (after Belgrade and Novi Sad). Niš is one of the most important industrial centers in Serbia, well-known for its industry of electronics and mechanical engineering, and the textile and the tobacco industry. The educational system is quite elaborate in the city: there are 50,000 pupils/students attending 32 primary, 21 secondary schools and 13 faculties.

In most cities in Serbia, the waste is disposed of in open dumps or unsanitary landfills endangering the environment and human health. In Serbia there are only seven sanitary landfills. The situation is similar in the city of Niš. At present, the city has a dysfunctional unsanitary landfill and waste management comes down to the collection and disposal of waste in the landfill. Amount of waste that generated in the city of Niš is 68,656 t per year (Faculty of Technical Sciences Novi Sad, 2009). The current situation in the city is such that the waste is collected by a public company and disposed of in unsanitary landfill. In the city there are several private companies involved in the recycling of waste (mainly metals, paper, plastics and e-waste). There are several locations with containers for the collection of recyclable materials (plastics, glass, aluminum cans, paper). The waste is collected and transported once a week. Waste collection is charged at the surface of the housing unit.

Questionnaire design

A questionnaire composed of 13 questions (statements) with pre-selected answers (1 – Strongly Disagree, 2 – Disagree, 3 – Undecided, 4 – Agree, 5 – Strongly Agree) was used for collecting data for this research. The questionnaire design is presented in Table 1.

Table 1 The submitted questionnaire

No.	Question
Personal attributes	Sex (Male; Female)
	Age
	Education level (Primary; Secondary; High)
Q_1	Waste is a big problem in my city.
Q_2	Waste problem in my city should be solved in other ways other than landfilling.
Q_3	Certain types of waste (paper, glass, metal, and plastic) can be recycled.
Q_4	I would do primary selection of waste in my household.
Q_5	Most of my friends would do primary selection of waste in their household.
Q_6	There are a sufficient number of containers of waste that can be recycled (plastic, glass, cans, and paper) in my city.
Q_7	Organic waste (plant residues, paper, yard waste, etc.) can be composted.
Q_8	The best way to solve the problem of waste is landfilling, recycling, incineration, composting.

Q_9	I'd agree that over a distance of 10 km from the place I live, build: sanitary landfill, recycling facility, incinerator, composting facility.
Q_{10}	Most of my friends would agree that over a distance of 10 km from the place they live, build: sanitary landfill, recycling facility, incinerator, composting facility.
Q_{11}	The biggest polluter is sanitary landfill, recycling facility, incinerator, composting facility.
Q_{12}	Waste disposal should be charged according to the amount of waste to be disposed.
Q_{13}	I would pay higher bills for waste collection and removal if they would solve the problem of waste pollution in my city.

Questions (statements) were designed to examine the public knowledge about certain waste treatment and their attitude about proposed waste treatment and their willingness to participate actively in their process of waste management, and a willingness to accept the construction of waste treatment facilities in their neighborhood.

The social acceptance cannot be determined response to one question from the survey, because very often, the population generally agrees with the proposed technology, but when it comes to implementation and the need to actively participate in the implementation of the decision, then the response is very small. It is therefore necessary, in determining the level of social acceptability of certain waste treatment, to take account of their opinion, knowledge and acceptance to participate in the implementation of waste management system.

In order to simplify the fuzzy model, as well as the number of inputs three questions in the survey were chosen, according to which, with sufficient reliability can determine level of social acceptability of waste treatment:

1) Q_8: The best way to solve the problem of waste is landfilling, recycling, incineration, composting.

2) Q_{11}: The biggest polluter is sanitary landfill, recycling facility, incinerator, composting facility.

3) Q_9: I'd agree that over a distance of 10 km from the place I live, build: sanitary landfill, recycling facility, incinerator, composting facility.

The sample of respondents

As shown in Table 2, the sample was extracted in order to reproduce the structure of the population of the City of Niš in terms of male and female percentages for each adopted age group: (1) 18–24, (2) 25–39, (3) 40–54, (4) over 55, and education level: primary, secondary and high.

Table 2 Demographic characteristics of population in the city of Niš and the sample of respondents

Demographic characteristics of population in the city of Niš											
Male	103,519	48.06%		18-24	25-39	40-54	>55	Education	Primary	Secondar	High
Female	111,862	51.94%		22,155	56,471	53,307	83,448		46,131	115,902	49,481
Total	215,381			10.29%	26.22%	24.75%	38.74%		21.42%	53.81%	22.97%

Characteristics of the sample of respondents											
Male	340	59.54%		18-24	25-39	40-54	>55	Education	Primary	Secondar	High
Female	231	40.46%		222	163	130	56		6	382	183
Total	571			38.88%	28.55%	22.77%	9.81%		1.05%	66.90%	32.05%

FUZZY MODEL

The decision to use the fuzzy method for development of model for evaluation of the sustainable indicators for waste management, social acceptance, was due to its effectiveness in the treatment of imprecise data and vague knowledge. Therefore, since the information available for social acceptance was insufficient, based on subjective assessment, and, in some cases, represented by estimations or inaccurate survey data, such logic resulted as the most valid methodology.

As previously emphasized, in order to apply the fuzzy logic, it is necessary to define the input data characterizing the problem under question, membership functions for each of them and defuzzification method, for obtaining the fuzzy output, which in the present case is the level of social acceptance of certain waste treatment.

Since there are no mathematical models to relate all parameters of social acceptance of waste treatment techniques, quantification of the level of social acceptance can only be based on subjective opinion of population. A fuzzy inference process has been introduced for facilitating social acceptance quantification, by using fuzzy membership functions and fuzzy rules.

In order to reduce the number of rules and manage the algorithm easily, the questions (Q_8, Q_9 and Q_{11}) previously indicated were used to define two different fuzzy inferences, as shown in the conceptual diagram in Figure 1.

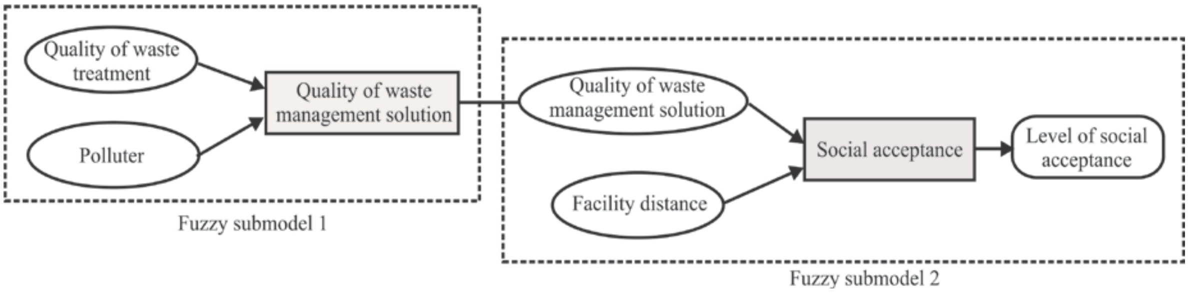


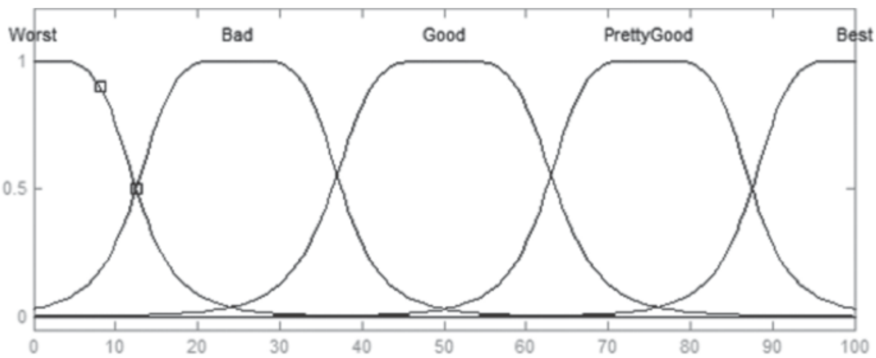
Figure 1 Conceptual diagram of the developed fuzzy model

The result obtained through the first fuzzy submodel was defined as Quality of waste management solution (QoS). The result obtained through the second fuzzy submodel, was defined as Social acceptance (SocAcc), by obtaining the level of social acceptance of waste treatment.

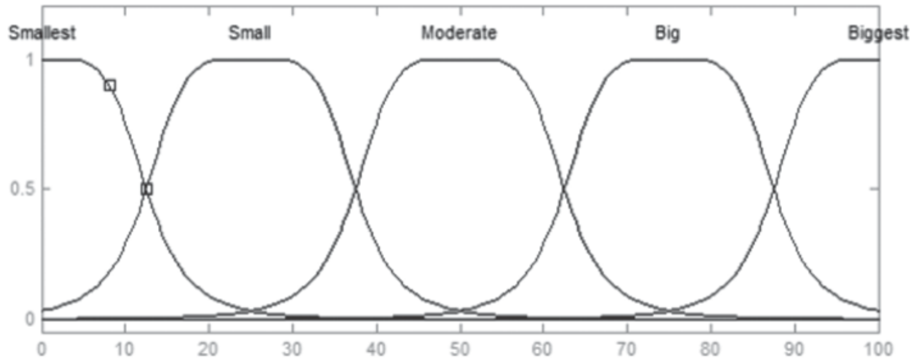
Quality of waste management solution, defined through inputs: Quality of waste treatment – answers on question Q_8 (The best way to solve the problem of waste is landfilling, recycling, incineration, composting.) and Polluter – answers on question Q_{11} (The biggest polluter is sanitary landfill, recycling facility, incinerator, composting facility.). The fuzzy sets defined for Quality of waste treatment were: the worst, bad, good, pretty good, and the best. The fuzzy sets defined for Polluter were: the smallest, small, moderate, big, and the biggest. That allowed us to obtain their opinion on the fact which waste treatment are considered the best with the different aspects (economic, environmental, or other).

Social acceptance, defined through inputs: Quality of waste management solution and Facility distance – answers on question Q_9 (I'd agree that over a distance of 10 km from the place I live, build: sanitary landfill, recycling facility, incinerator, composting facility.). The fuzzy sets defined for Facility distance were: totally disagree, disagree, slightly agree, agree and totally agree.

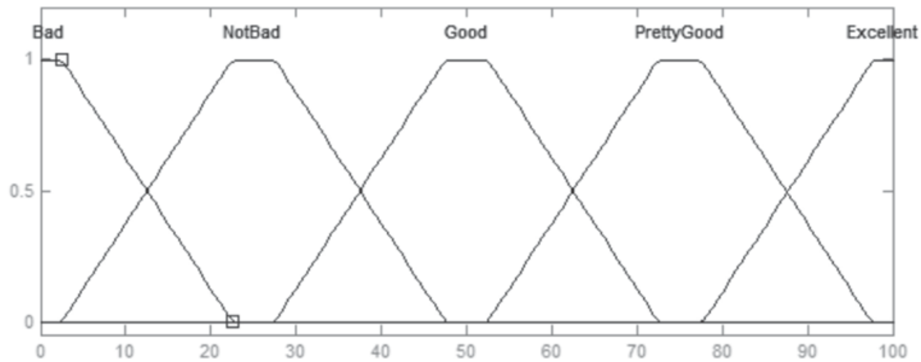
The membership functions defined for input and output variables for the first submodel are shown in Figure 2.



(a)



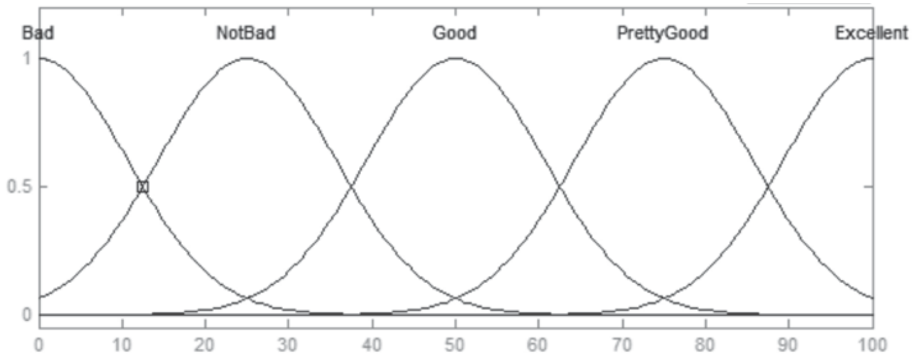
(b)



(c)

Figure 3 Membership functions for input and output variables for the first submodel: (a) Input variable “Quality of waste treatment”, (b) Input variable “Polluter”, (c) Internal variable “Quality of waste management solution”

The membership functions defined for input and output variables for the second submodel are shown in Figure 3.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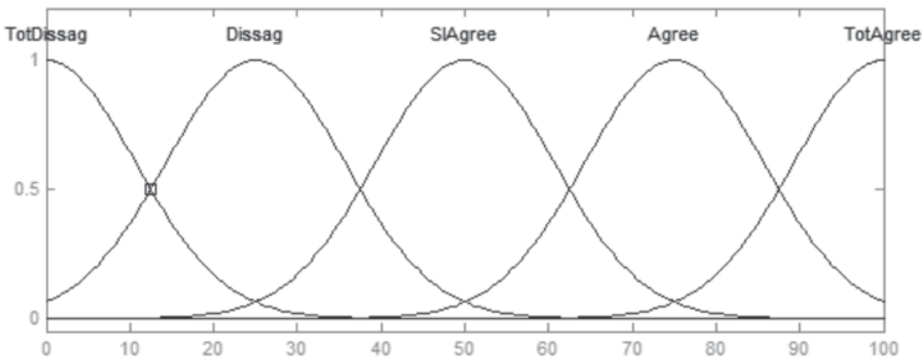
(a)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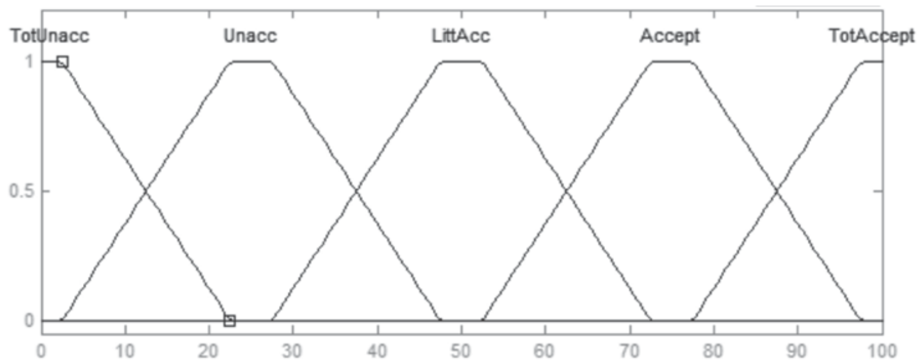
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(c)

Figure 4 Membership functions for input and output variables for the second submodel: (a) Internal variable “Quality of waste management solution”, (b) Input variable “Facility distance”, (c) Output variable “Social acceptance”

The rules usually contain a conditional part (e.g. antecedent) and a conclusion part (e.g. consequence). An antecedent may be a simple clause or may be a combination of several clauses connected via fuzzy logical operators “and”, “or”, and “not”. In the assignment of the rules (Table 3) in the first fuzzy inference, we defined that the increase in Quality of waste management solution is favored by low pollution and increasing in quality of waste treatment. For example (Table 3), ‘‘if quality of waste treatment” is bad and ‘‘if polluter” is big then the Quality of waste management solution is bed.

Table 3 Fuzzy rules for determining the first fuzzy submodel

Polluter	Quality of waste treatment				
	Worst	Bad	Good	Pretty good	Best
Smallest	Not bad	Not bad	Good	Pretty good	Excellent
Small	Bad	Not bad	Good	Good	Pretty good
Moderate	Bad	Bad	Not bad	Not bad	Good
Big	Bad	Bad	Bad	Bad	Not bad
Biggest	Bad	Bad	Bad	Bad	Bad

At the other hand, in the assignment of the rules (Table 4) in the second fuzzy inference, we defined that the increase in Social acceptance is favored by increasing in Quality of waste management solution, and proximity to facility distance.

Table 4 Fuzzy rules for determining the second fuzzy submodel

Facility distance	Quality of waste management solution				
	Bad	Not bad	Good	Pretty good	Excellent
Totally disagree	Totally unacceptable	Totally unacceptable	Unacceptable	Unacceptable	Unacceptable
Disagree	Unacceptable	Unacceptable	Unacceptable	Little acceptable	Little acceptable
Slightly agree	Unacceptable	Little acceptable	Little acceptable	Acceptable	Acceptable
Agree	Little acceptable	Little acceptable	Acceptable	Acceptable	Totally acceptable
Totally agree	Little acceptable	Acceptable	Acceptable	Totally acceptable	Totally acceptable

The final result of the process was obtained through defuzzification, which supplied a numerical value included between 0 and 100% and represented the level of social acceptance of certain waste treatment.

In general, for each of the two serial fuzzy submodels we defined: the type of membership function, membership classes, fuzzy rules (Tables 3 and 4) and defuzzification method, thus obtaining the numerical results related to Quality of waste management solution and Social acceptance.

RESULTS AND DISCUSION

After processing the responses on question Q_1, obtained in the survey, the results show that 80.74% of respondents are aware that in the city there is the problem of inadequate waste management, and 85.64% of them know that there are other waste treatments except landfilling (response on question Q_2).

Examination of knowledge of waste treatment shows that 80.56% of respondents know that certain types of waste (paper, glass, metal, plastic) can be recycled, and 62.70% of respondents know that organic waste (plant residues, paper, garden waste, etc.) can be composted. Those results demonstrate a high level of knowledge about waste treatments with recourse recovery (recycling and composting).

Figure 4 shows the attitude of respondents about waste treatment techniques (question Q_8). 77.23% of respondents think that recycling is the best way of waste treatment, while only 23.82% of them think that incineration is the best way of waste treatment. This may be the result of lack of knowledge related to the benefits of incineration (waste volume reduction and energy recovery from waste), and can also be a result of fear of environmental pollution by burning waste, because 57.09% of respondents believe that the incinerator is the biggest polluter of the environment, of all waste treatment facilities. It is probably because of that, only 16.29% of respondents would agree that over a distance of 10 km from the place they live build the incinerator facility. It means that syndrome "Not In My Back Yard" (NIMBY) is present in the population of Niš, as well as in the majority of world population.

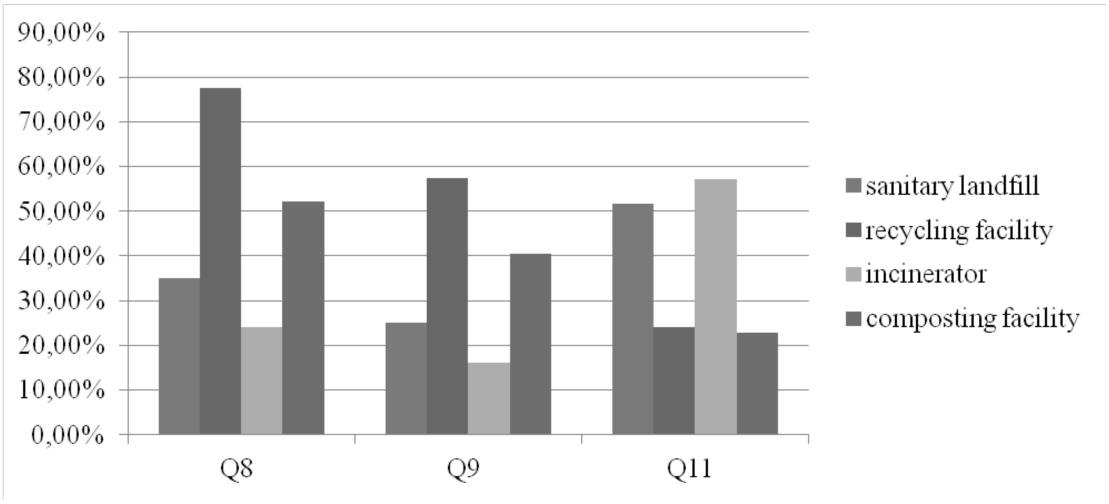

Figure 2 Acceptance and opinion about waste treatments

The result which shows that 51.14% of respondents thought that the biggest polluter of the environment is sanitary landfill, means that respondents equate unsanitary and sanitary landfill, and they do not have enough knowledge about the impacts of certain waste treatment facilities on the environment (landfilling, incineration).

Above mentioned results (responses on questions Q_8, Q_9 and Q_{11}), obtained by the survey in the city of Niš, as well as the application of the developed fuzzy model, the level of social acceptance of certain waste treatments (landfilling, recycling, incineration, and composting) was calculated. The obtained results are shown in Table 5.

Table 5 Level of social acceptance

	Landfilling	Recycling	Incineration	Composting
Quality of waste treatment	36.96 %	77.54 %	24.09 %	52.09 %
Polluter	51.63 %	24.09 %	57.07 %	22.83 %

Facility distance	25.18 %	57.43 %	16.12 %	40.58 %
Level of social acceptance	24.61 %	55.32 %	17.87 %	50.65 %

The obtained results show that the highest level of social acceptance in the city of Niš is for recycling (55.32 %), and after that for composting. The lowest level of social acceptance is for incineration.

CONCLUSION

Social indicators (social acceptability, job creation, social benefits, social equity, etc.) are mostly qualitative character. Measuring sustainability and quantifying the social dimension of sustainability are difficult tasks. Also, determination of social indicators involves a great deal of uncertainty. Those are the main reasons for using fuzzy set theory and fuzzy logic, because they provide an approach to deal with uncertainty.

The presented study suggests an innovative methodology for evaluation of level of social acceptance of certain waste treatment based on fuzzy logic approach.

In order to determine the value of social indicators, such as social acceptance, survey was carried out of the sample of 571 respondents in the adult population. A set of questionnaire which comprised of 13 questions was applied as an instrument for data collection.

The results of survey show that 80.74% of respondents are aware that in the city there is the problem of inadequate waste management, and 85.64% of them know that there are other waste treatments except landfilling. 51.84% of respondents considered billing system inadequate, and agrees to the collection and transportation of garbage should be charged according to the amount of waste to be disposed, however, but only 49.56% of respondents are willing to pay higher bills for waste collection and transportation if they would solve the problem of waste pollution in the city.

The survey also showed lack of knowledge about influence of individual waste treatment on the environment, which leads to the conclusion that it is necessary to carry out continuous education and learning population with possible ways of waste treatment and their effect on the environment to reduce the negative impact syndrome NIMBY the implementation of certain waste treatment.

The developed fuzzy model allows to evaluate the level of social acceptance of certain waste treatment, using three input variable (Quality of waste treatment, Polluter, and Facility distance). The results obrained in the survey are used to verify the developed fuzzy model. According to that, it can be concluded that the highest level of social acceptance in the city of Niš is for recycling (55.32 %), and the lowest level of social acceptance is for incineration (17.87 %).

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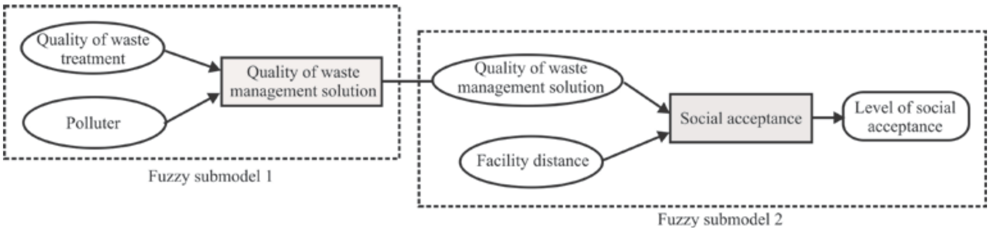
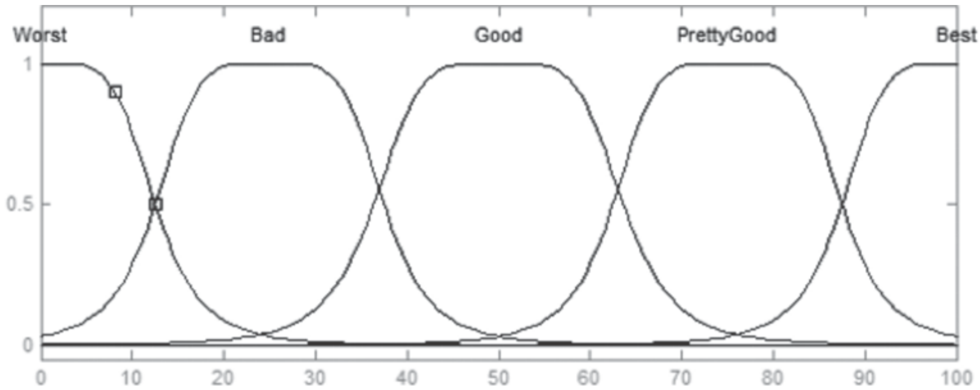
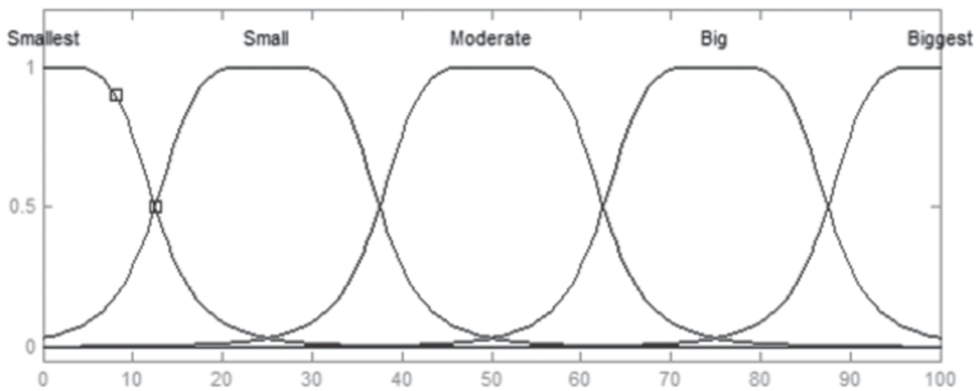


Figure 3 Conceptual diagram of the developed fuzzy model


Worst
Bad
Good
PrettyGood
Best
1
0.5
0
0 10 20 30 40 50 60 70 80 90 100
(a)


Smallest
Small
Moderate
Big
Biggest
1
0.5
0
0 10 20 30 40 50 60 70 80 90 100
(b)

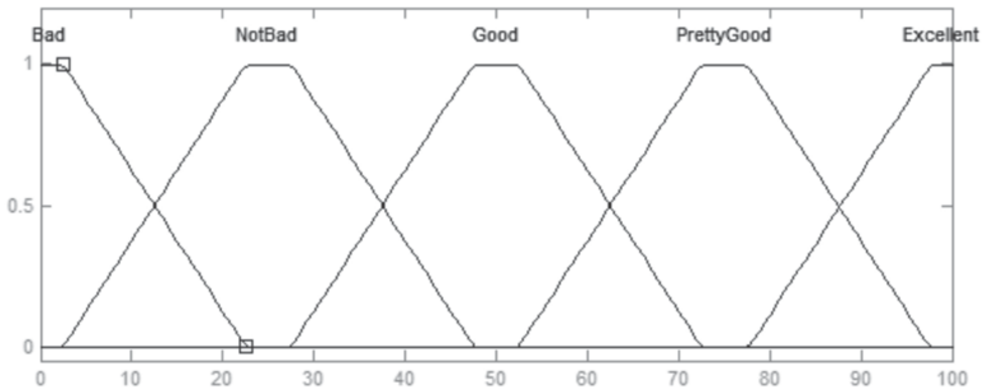
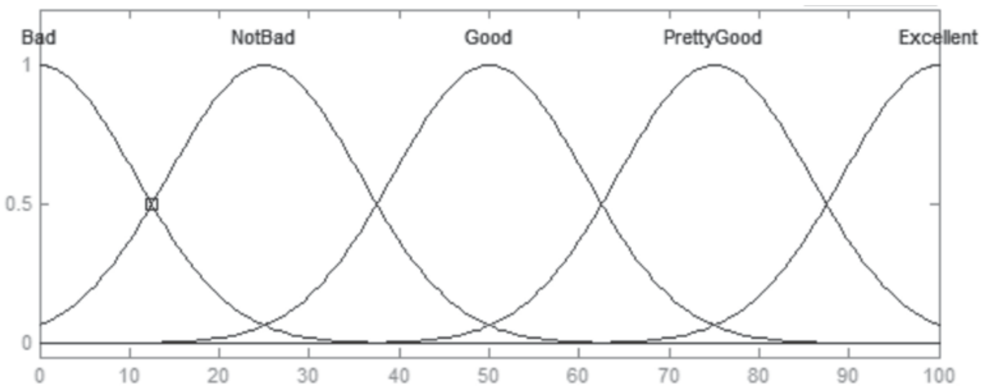
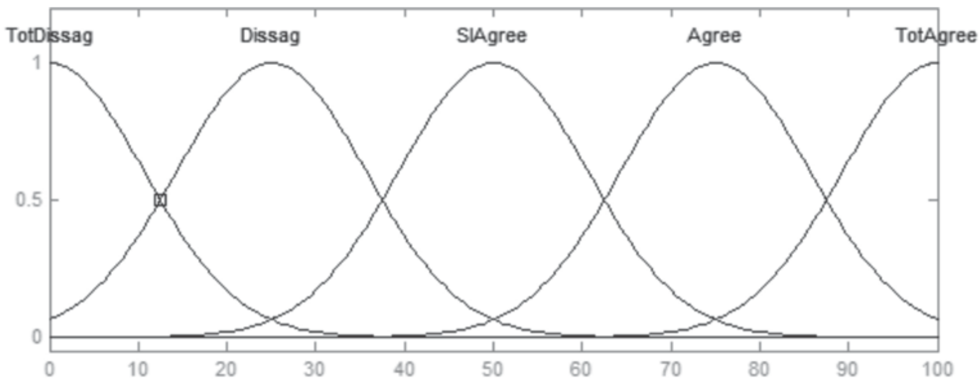

Bad
NotBad
Good
PrettyGood
Excellent
1
0.5
0
0 10 20 30 40 50 60 70 80 90 100
(c)

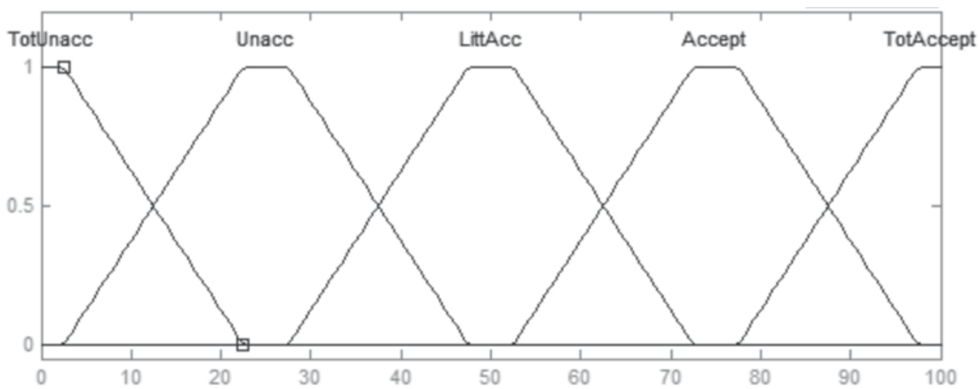
Figure 3 Membership functions for input and output variables for the first submodel: (a) Input variable “Quality of waste treatment”, (b) Input variable “Polluter”, (c) Internal variable “Quality of waste management solution”


Bad
NotBad
Good
PrettyGood
Excellent
1
0.5
0
0 10 20 30 40 50 60 70 80 90 100

(a)


TotDissag
Dissag
SlAgree
Agree
TotAgree
1
0.5
0
0 10 20 30 40 50 60 70 80 90 100

(b)


TotUnacc
Unacc
LittAcc
Accept
TotAccept
1
0.5
0
0 10 20 30 40 50 60 70 80 90 100

(c)

Figure 4 Membership functions for input and output variables for the second submodel: (a) Internal variable “Quality of waste management solution”, (b) Input variable “Facility distance”, (c) Output variable “Social acceptance”

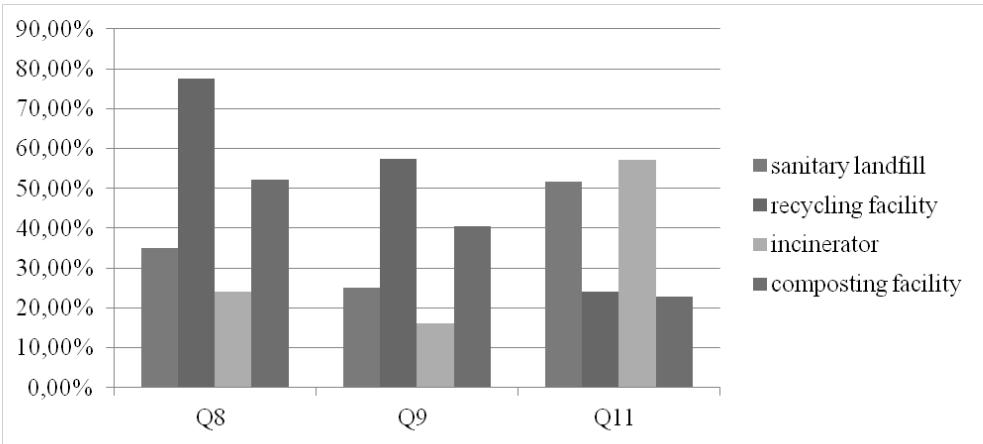


Figure 4 Acceptance and opinion about waste treatments

Table 6 The submitted questionnaire

No.	Question
Personal attributes	Sex (Male; Female)
	Age
	Education level (Primary; Secondary; High)
Q_1	Waste is a big problem in my city.
Q_2	Waste problem in my city should be solved in other ways other than landfilling.
Q_3	Certain types of waste (paper, glass, metal, and plastic) can be recycled.
Q_4	I would do primary selection of waste in my household.
Q_5	Most of my friends would do primary selection of waste in their household.
Q_6	There are a sufficient number of containers of waste that can be recycled (plastic, glass, cans, and paper) in my city.
Q_7	Organic waste (plant residues, paper, yard waste, etc.) can be composted.
Q_8	The best way to solve the problem of waste is landfilling, recycling, incineration, composting.
Q_9	I'd agree that over a distance of 10 km from the place I live, build: sanitary landfill, recycling facility, incinerator, composting facility.
Q_{10}	Most of my friends would agree that over a distance of 10 km from the place they live, build: sanitary landfill, recycling facility, incinerator, composting facility.
Q_{11}	The biggest polluter is sanitary landfill, recycling facility, incinerator, composting facility.
Q_{12}	Waste disposal should be charged according to the amount of waste to be disposed.
Q_{13}	I would pay higher bills for waste collection and removal if they would solve the problem of waste pollution in my city.

Table 7 Demographic characteristics of population in the city of Niš and the sample of respondents

Demographic characteristics of population in the city of Niš											
Male	103,519	48.06%		18-24	25-39	40-54	>55	Education	Primary	Secondar	High
Female	111,862	51.94%		22,155	56,471	53,307	83,448		46,131	115,902	49,481
Total	215,381			10.29%	26.22%	24.75%	38.74%		21.42%	53.81%	22.97%
Characteristics of the sample of respondents											
Male	340	59.54%		18-24	25-39	40-54	>55	Education	Primary	Secondar	High
Female	231	40.46%		222	163	130	56		6	382	183
Total	571			38.88%	28.55%	22.77%	9.81%		1.05%	66.90%	32.05%

Table 8 Fuzzy rules for determining the first fuzzy submodel

Polluter	Quality of waste treatment				
	Worst	Bad	Good	Pretty good	Best
Smallest	Not bad	Not bad	Good	Pretty good	Excellent
Small	Bad	Not bad	Good	Good	Pretty good
Moderate	Bad	Bad	Not bad	Not bad	Good
Big	Bad	Bad	Bad	Bad	Not bad
Biggest	Bad	Bad	Bad	Bad	Bad

Table 9 Fuzzy rules for determining the second fuzzy submodel

Facility distance	Quality of waste management solution				
	Bad	Not bad	Good	Pretty good	Excellent
Totally disagree	Totally unacceptable	Totally unacceptable	Unacceptable	Unacceptable	Unacceptable
Disagree	Unacceptable	Unacceptable	Unacceptable	Little acceptable	Little acceptable
Slightly agree	Unacceptable	Little acceptable	Little acceptable	Acceptable	Acceptable
Agree	Little acceptable	Little acceptable	Acceptable	Acceptable	Totally acceptable
Totally agree	Little acceptable	Acceptable	Acceptable	Totally acceptable	Totally acceptable

Table 10 Level of social acceptance

	Landfilling	Recycling	Incineration	Composting
Quality of waste treatment	36.96 %	77.54 %	24.09 %	52.09 %
Polluter	51.63 %	24.09 %	57.07 %	22.83 %
Facility distance	25.18 %	57.43 %	16.12 %	40.58 %
Level of social acceptance	24.61 %	55.32 %	17.87 %	50.65 %